TX-0 COMPUTER
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A PROPOSAL FOR TIME SHARED OPERATION OF TX-0

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This memorandum is a description of a system for time-shared operation of the TX-0 computer by several users, primarily to provide for greatly increased efficiency of program testing. The additional equipment needed for realizing the system is specified below, and its mode of operation is described. Up to eight keyboard-printer consoles would be provided for communicating with the machine. Duplication of the TX-0 display system is not proposed here. Therefore, only one user could conveniently use the CRT and light pen at any one time. Adding a second display system is possible, but at considerable expense and effort.

With the mode of operation outlined below, about 25% of the TX-0 capacity (instructions per second) would be used for managing input and output, and 20% would be used for changing active programs leaving 55% of capacity for the active programs under the worst possible conditions. Currently, it is estimated that 3% or less of the TX-0 capacity is efficiently utilized in the program testing activities for which the time-sharing system would be employed. Thus, there would be more than adequate capacity to handle the program testing needs of users at eight consoles. It is visualized that the time-sharing system would be in operation for about half of the time TX-0 is in use. The remaining time would be used for production running of checked-out programs. However, the features included for time-shared operation would also greatly facilitate production processing.

Hardware Requirements

1. A disk file or equivalent--for storage of utility programs, systems, and users' programs. The magnetic tape system now being completed could substitute for this but with a great sacrifice in speed of operation.

2. Consoles consisting of keyboard and printer.

3. Additions to central computer to allow for a protected area of core memory, modification of the read-in mode, additional select commands, etc. These additions will be minor relative to the changes currently being installed.

Normal Condition of Memory

Figure 1 shows the assignment of memory. The protected area of memory will probably be 512 registers in length and contains an executive routine plus a block of buffer registers for each console and paper tape punch. The remainder of memory is available for users' programs, a utility program or an assembler or compiler according to the need. It is assigned to successive users in rotation as described later.

Functions of the Executive Routine

The executive routine has three functions: The first is to manage the order in which control is assigned to the various programs competing for time. The second is to manage the buffering of input information from console keyboards, and output information printed at the consoles or punched into paper tape. The third is to assign other in-out devices (3 magnetic tape units, 2 paper tape readers, 2 punches and external equipment commands) to specific programs, so that there can be no interference by one program with the input/output affairs

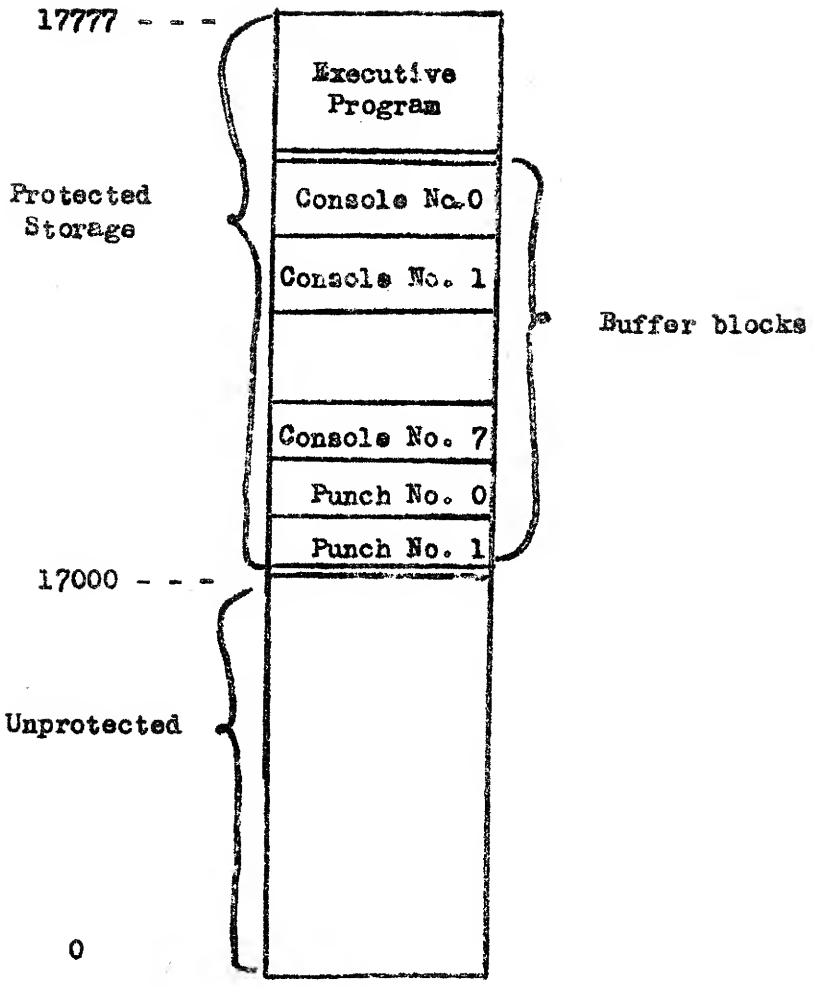

Figure 1 -- Memory Assignment

of another. The manner in which these functions are realized is discussed below.

Transfer of Control to the Executive Routine

Control is transferred to the executive routine by means of program interruption features which would be a simple extension of the TX-0 read-in mode. Interrupt action would preserve sufficient information about the conditions of machine registers so that the executive routine may restart the program interrupted to continue the computation as though no interruption had occurred. The following conditions will cause this interruption to occur:

1. A time limit is reached.
2. A TYP, PRT, P6H or P7H instruction is encountered by the active program.
3. A HLT instruction is encountered.
4. An illegal instruction is encountered.

Protection and the Executive Flip-Flop

There will be an "executive" flip flop added to the TX-0, which will be "on" whenever the executive routine is operating. It will be turned on only when an interrupt occurs, and will be turned off by the executive routine at the time control is given to an active program. The effect of the executive flip-flop on computer operation is as follows:

1. Executive flip-flop off:
   a. Any reference to the protected storage area makes an instruction illegal.
   b. Instructions TYP, PRT, P6H, P7H will cause interrupt.
   c. Instructions altering the assignment of input-output devices are illegal.
   d. Instructions attempting to address a protected area of the disk file are illegal.

2. Executive flip-flop on:

a. References to protected area of core memory are permitted.

b. Instructions TYP, PRT, P6H, P7H have their normal function as described below.

c. Alteration of in-out assignment is allowed.

d. All disk locations may be addressed.

Inhibition of Interrupt

Interrupt action will be delayed under the following conditions:

a. The executive program is operating, and hence the executive flip-flop is on.

b. An active program is in process of reading or writing a record on magnetic tape, paper tape or disk.

Consoles

Each console will be equipped with a keyboard and printer (Flexowriter, Lincoln writer equipment, or perhaps something better), a couple of indicating lights and a push button. The console can be placed in one of three conditions by a select instruction executable only by the executive routine (a restricted select instruction):

1. deselected--keyboard and printer not connected to computer. Characters typed on keyboard printed, but not transferred to computer.

2. print--print indicated light on, keyboard locked. Computer printing output information.

3. read--read indicator light turned on. Computer accepting information typed. Keyboard locked if computer not ready.

The console push button allows the users to manually interrupt his program and return control to the utility program he was using so that the state of his program may be determined.

Operation of TYP, PRT, P6H, P7H, instructions

Associated with each colsole and paper tape punch will a one character buffer register and a flag flip-flop which can be examined by the executive routine. The console to which TYP and PRT instructions refer is determined by a three-bit "console select register" which is set by a restricted select instruction. When a character is typed on any keyboard in "read" status it is entered in the corresponding buffer register and its flag is set. When a TYP instruction is subsequently given by the executive routine, the contents of the buffer are placed in the TX-0 Live Register, and the flag is reset. The TYP instruction will require only 12 microseconds.

A PRT instruction given by the executive routine will transfer bits from the TX-0 Accumulator to the buffer determined by the console select register and clear the associated flag. It will be executed in 12 microseconds. When the console printer completes printing of the character, the flag is set.

The operation of P6H and P7H instructions given by the executive routine is similar to PRT, except which of a pair of punches is actuated is determined by a one bit "punch select register".

Executive Routine Control of Typing, Printing and Punching

As mentioned earlier, there will be an automatic interrupt which occurs every 15 milliseconds, at which time the flag register will be examined by the executive program. If no flags are set, one will be added to an interruption count, and control will be returned to the active program if the count does not exceed a limit. The whole operation will require approximately 240 microseconds, which represents less than 2% of the 15 millisecond interval.

If any flags are set, the executive routine will take appropriate action:

1. A console in read status--select the console, give a TYP instruction, and store the character in the appropriate buffer block.

2. A console in print status--select the console, read the next character from the appropriate buffer block and print by means of a PRT instruction.

3. Paper tape punch--select the punch and punch one character from the appropriate buffer block.

Assuming that 80 instruction executions or about 1 milisecond would be required for each of these operations, the following fraction of TX-0 capacity would be required for each unit:

Typewriter in read status (4 characters per second)

0.4%

Typewriter in print status (12 characters per second)

1.2%

Paper tape punch (60 characters per second)

6.0%

Thus, simultaneous operation of two punches and eight console printers at maximum rate would use up only

$$2 \times 6.0 + 8 \times 1.2 + 2 = 24\%$$

of the TX-0 instruction speed, leaving at least 75% of instruction speed for the active program.

If the maximum interrupt count is exceeded, the count will reset and a new program attains active status. The maximum interrupt count will be of the order of 50 corresponding to a time interval of about one second.

Execution of TYP, PRT, P6H and P7H Instructions in an active program

The appearance of a TYP, PRT, P6H or P7H command in an active program will cause an interrupt and the executive routine will take the following action:

1. TYP--Place character from appropriate buffer block in TX-0 Live Register and return to active program. If buffer block is empty, a new active program will be selected.
2. PRT, P6H, P7H--Place character from TX-0 Accumulator in appropriate buffer block and return to active program. If the buffer block is full, a new active program will be selected.

Again, each of these operations will require approximately 80 instruction execution times or one millisecond. However, this is a great decrease from the present 80 millisecond delay involved in printing a character, the 16 millisecond delay for punching or the arbitrary delay for the user to type his next direction.

Selection of Active Programs

When the executive routine determines that a new program should be given active status, the consoles will be considered in sequence, and the first one not waiting for input or output will be selected. The process of switching active programs consists in writing the present status of the present active program at a specific location in the disk file, and reading the new active program from another location. The time required for this process will be determined primarily by the access time and data rates of the equipment used. It is felt that operating the disk file through a channel system as with the 709, could require too extensive modifications to the TX-0 to be worth considering. Therefore, the entire time, both access and data transmission would represent lost computation capacity to the active programs. A reasonable guess at the time required is 012 seconds. If more than one console was operating and not waiting for input, this would mean that 20% of the time would be used for switching active programs.

Since the same utility or assembly program may be in use by several consoles at one time, the executive routine would attempt to order the consoles according to their needs so that the number of disk to memory transfers is reduced.